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MEASUREMENT OF COSMIC RAYS AT AGRA AND KODAIKANAL

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(Received for publication, April 8, 1940)

Plates VIII & IX

ABSTRACT. Cosmic-ray intensities have been measured at Agra and Kodaikanal by means of a Kolhörster apparatus with a shield of iron 5″·5 thick. The intensities have been reduced to standard pressures, for Agra and Kodaikanal separately, by means of the regression coefficients calculated from the intensity and pressure data. The mean intensity values obtained after correcting for barometer effect are for Agra $1{\cdot}545 \pm 0{\cdot}007$ and for Kodaikanal $2{\cdot}333 \pm 0{\cdot}010$ pairs of ions $cm.^{-3}$ $sec.^{-1}$

From these values, after allowing for latitude effect the absorption coefficient of cosmic rays has been calculated. The absorption coefficient obtained, *viz.*, 0·202 per metre of water agrees well with the values obtained by Millikan and Cameron.

By means of this coefficient of absorption the absolute intensities of cosmic rays without shield have been deduced. These values of 2·007 and 1·925 pairs of ions per cm^3 sec^1 for Kodaikanal and Agra respectively compare well with Compton's intensity values for the same latitudes. The intensity data for Agra and Kodaikanal are then analysed according to mean and sidereal times. The curves for the mean solar time for the two stations agree with each other and with the corresponding curves of other investigators but no similarity has been found between the sidereal time curves of the two stations.

Mean daily cosmic-ray intensities have been correlated with solar activity represented by sunspot numbers and flocculi figures but no relationship has been found to exist between them.

In recent times the geographical distribution of cosmic-ray intensities has formed one of the important aspects of the study of cosmic radiation. The world surveys of cosmic radiation organized by A. H. Compton and by R. A. Millikan have shown the utility of such studies particularly with regard to the discovery of the nature of the particles which constitute this radiation. In spite of these expensive surveys it has not been possible, we believe, to collect data from as many representative countries as would have been desirable and it is likely to be helpful for a general study to secure observational data from such latitudes as do not seem to have been well represented in the world surveys. India seems to be one of the countries from which very little data on cosmic ray intensity are available. The only references that we have been able to find about this type of work in India are the measurements by J. M. Benade in August, 1932, at Lahore under the scheme of co-ordination initiated by Compton [1] and the balloon observations made at Madras in October, 1936, by H. V. Neher [2], a collaborator of Millikan. The measurements considered in the present paper, though not numerous, have therefore appeared to us to be worth publishing. It is, however, intended that the measurements should be continued for a few years in order to obtain a sufficiently long series of data capable of yielding definitive values of the intensity of cosmic radiation in India.

EXPERIMENTAL ARRANGEMENTS

The measurements discussed in this paper were made at Agra (Lat. 27° 8′ Long. 78° 1′) and at Kodaikanal (Lat. 10° 14′ Long. 77° 28′). Although the choice of these two stations was dictated by reasons other than the requirements of this investigation, these stations happen to represent typical localities well suited for this kind of work. They differ appreciably in latitude and considerably in altitude, Agra being practically a sea-level station about 554 feet above mean sea level and Kodaikanal a hill station about 7700 feet above mean sea level. The apparatus used for these observations was a Kolhörster electroscope of the latest type belonging to the India Meteorological Department. It had proved to be perfectly satisfactory for the measurements of cosmic radiation made by one of us (A.K.D.) during two sea voyages between India and Europe and at Cambridge.[3] As it has frequently been contended by workers on cosmic rays that intensity measurements are affected by instrumental bias, it seems desirable to give a brief description of our apparatus although the principle of this instrument is well known from Kolhörster's descriptions. The complete apparatus shown in Plate VIII consists of a cylindrical ionisation chamber 'A' made of sheet iron 2·5 mm thick and fitted with a brass lid of 3·5 mm. thickness. The chamber is sealed air-tight and filled with air (at nearly atmospheric pressure) specially dried and freed from radio-active substances. The air-tightness of the ionisation chamber can be checked by means of a thermometer 'T' and a precision aneroid barometer 'P' attached to the instrument. The electrometer is sealed inside the ionisation chamber and its deflections can be read with the help of a microscope fitted to the lid. It consists of a pair of exactly similar loops of quartz fibre mounted on a frame with a nickel-steel-quartz temperature compensation, the frame being fixed upon the objective of the viewing microscope. The electrometer being well insulated from the walls of the ionisation chamber, the loss of charge through leakage is extremely small. Through the microscope the quartz loops can be seen only edgewise so that they appear as two straight dark filaments against the microscope scale divisions. The filaments and the scale divisions are illuminated by means of a small

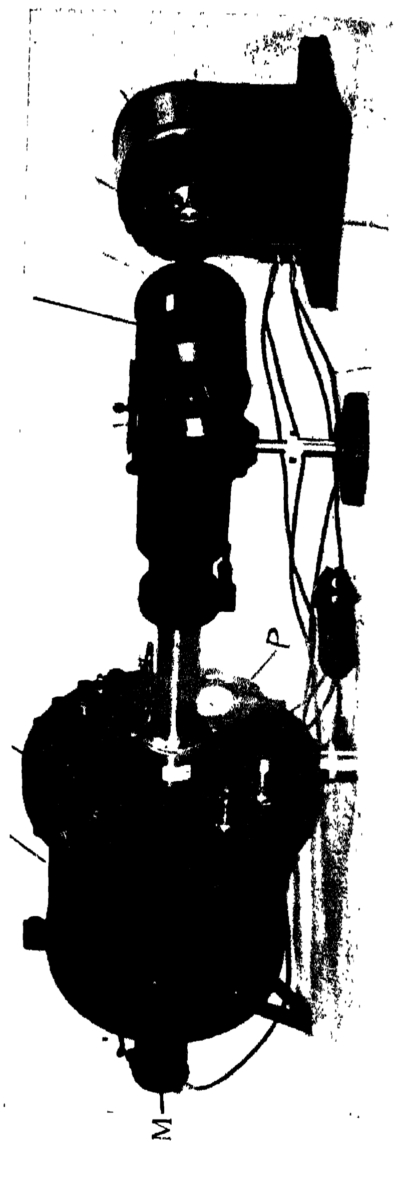
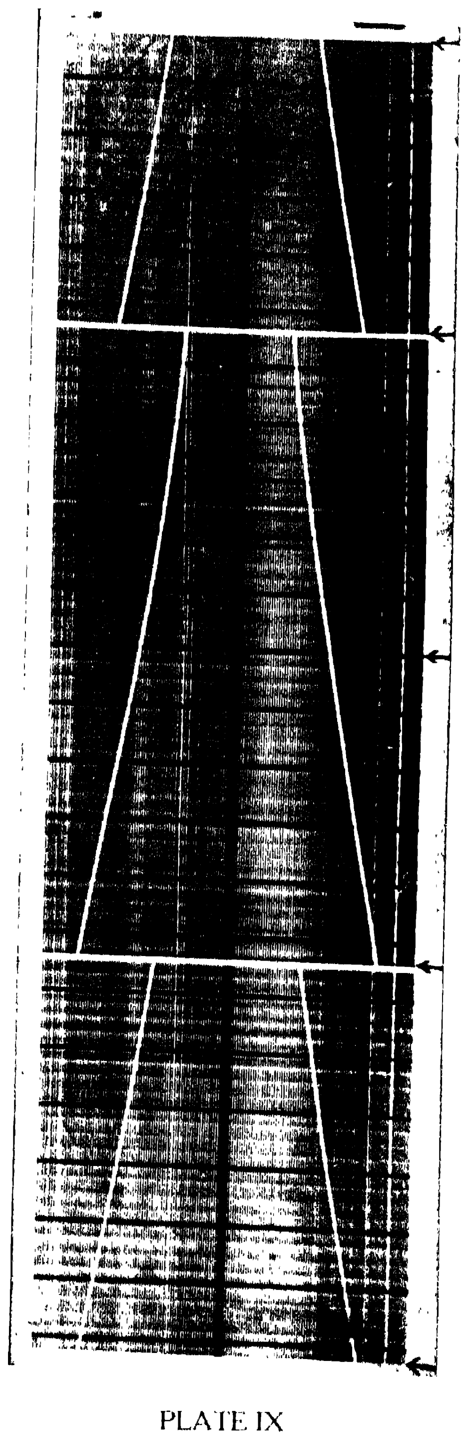


PLATE VIII

KODAIKANAL CHART No. 8 (Feb. 17–18)



$14^h\text{-}50^m$ 21-45 3-12 8-40 13-51

SAMPLE RECORD FROM KOLHÖRSTER'S APPARATUS

PLATE IX

electric lamp fitted inside a metal tube 'M' and screwed on to the window at the back of the ionisation chamber. The instrument can be used for visually reading the deflections of the electroscope ; it is, however, provided with a camera 'C' (with a rotating drum for photographic paper) which can be fixed on the eye piece end of the microscope for obtaining a continuous photographic record of the separation of the electroscope filaments. For the present observations, the latter method was exclusively employed.

The walls of the ionisation chamber are thick enough to prevent any α or β rays from entering it ; but in order to eliminate the possible effect of even the most penetrating γ rays of known radio-active origin, the apparatus was enclosed in an iron shield of 5·5 inches thickness all round. The shield was built up as a rectangular box from several iron plates for convenience of manipulation. For charging the electrometer at intervals, it was necessary to make one wall of the shield easily removable and consequently it was found essential to keep down its weight as much as possible. Accordingly, the shield was made just large enough to enclose the ionisation chamber only, so that the end of the microscope tube carrying the camera projected out of the shield through a hole in the movable wall. The movable wall itself had to be made of two halves mounted in such a way that they could be slid along iron grooves with ball runners. This arrangement necessarily involved a certain amount of leakage of γ rays into the ionisation chamber, but we do not think that it could have been large enough to affect materially the measurements of the cosmic rays.

The experimental material utilised in this work consists of complete records for 23 days in June-July, 1936, at Agra and for 13 days in February, 1938, at Kodaikanal. At Agra the whole apparatus was installed in a canvas tent well away from buildings and at Kodaikanal the apparatus was housed in a wooden hut previously used for housing magnetic instruments. The electrometer was charged each time to about 300 volts and was allowed to discharge itself till the voltage dropped to 100 volts. Below 100 volts the ionisation current no longer corresponded to saturation, so that the electrometer had to be charged up again. This necessitated charging the electrometer twice a day at Agra and three times daily at Kodaikanal where the loss of charge through ionisation was faster. Charging of the electrometer was done with the help of a magnetic probe and a charging terminal fixed on the lid of the ionisation chamber but insulated from it by means of an amber insulator. The battery used for charging was a Zamboni pile the positive pole of which was connected to the charging terminal of the electrometer, the other pole being earthed. The probe which is inside the ionisation chamber was then brought into contact with the inner end of the charging terminal by turning it over with the help of a horse-shoe magnet attached to the outside of the lid. The charging now finished, the probe was again turned back to its initial position so as to keep the electrometer disconnected from the charging terminal. The separation of the electrometer filaments when charged could be observed through a window in the camera by means of a reflex arrangement. The time of the opening or the closing of the shutter was noted whenever this was done for charging the electrometer or for changing the photographic paper. A sample record obtained from the instrument is shown in Plate IX. This is a copy of the Kodaikanal record of February 17-18, 1938 on a reduced scale. There are three pairs of electrometer traces on the chart. Each pair begins with full charge when there is the greatest seperation between the filament traces and then gradually the traces come nearer together as the charge decreases. The very fine and close lines running along the sheet are the traces of the microscope scale divisions. The rather thick lines across the sheet are the hour marks which are registered by means of a device in the clock work which short-circuits the lamp once every hour. The sheets were measured by means of a low-power travelling microscope. The procedure was to count the number of scale divisions between the electrometer traces at every hour mark and at every point corresponding to the time of the opening and closing of the exposing shutter. The times corresponding to the hour marks were deduced from the times of the opening and closing of the shutter after making due allowances for the rate of the clock. The linear distances between the electrometer traces, *i.e.*, the number of scale divisions counted, were then converted to volts by means of a calibration curve prepared by one of us (A.K.D.) with the help of a fine precision potentiometer at the Electrical Engineering Laboratory of the University of Cambridge.

Since all other sources of ionisation have been eliminated by the use of the iron shield, the loss of charge of the electrometer must be due to cosmic rays alone. Accordingly the rate of ion formation is a measure of the intensity of the cosmic radiation. In order to obtain the rate of ionisation, all the readings of the electrometer in volts were tabulated against the corresponding times so that the values of volt difference (dv) and of time difference (dT) were directly obtained from the tables. The rate of ionisation, *i.e.*, the number of ion-pairs per cm.^{3} per second, was then calculated according to the usual formula for this kind of instrument.

$$J = \frac{C}{300 \times 60 \times e \times L} \cdot \frac{dv}{dT} = 8{\cdot}193 \cdot \frac{dv}{dT},$$

where J = number of ion-pairs/cm.^{3}/sec., C = capacity of the electrometer $= 0{\cdot}268$ cm.

L = internal volume of the ionisation chamber reduced to 0°C and 760 mm. pressure $= 3801{\cdot}06$ cm.^{3}, e = electronic charge $= 4{\cdot}78 \times 10^{-10}$ e.s.u. and $\frac{dv}{dT}$ = decrease of voltage per minute.

The residual ionisation of the apparatus, as determined and given by the makers, Günther and Tegetmeyer of Braunschweig, is 1·145 ion-pairs per cm.^{3} per second. By subtracting this value of the residual ionisation from the total ionisation represented by J, the ionisation due to external causes or the intensity of cosmic rays 'I' was obtained.

BAROMETER EFFECT

The intensity of cosmic radiation measured at the surface of the earth must be expected to be influenced by meteorological conditions and consequently it is essential to reduce all observations made at different times to standard meteorological conditions in order that they may be comparable. The atmospheric factor which affects cosmic-ray intensity most is the barometric pressure, the effect of temperature, humidity and other elements being comparatively small. This fact observed by most investigators, was brought out very clearly by the method of multiple correlation used by A. Corlin [4] who obtained the following correlation coefficients for pressure (RIB) temperature (RIT) and humidity (RIH) for the three periods for which he analysed his data.

Period	I	II	III
RIB	−0·585 ± 0·030	−0·369 ± 0·040	−0·456 ± 0·054
RIT	−0·157 ± 0·045	−0·023 ± 0·047	+0·059 ± 0·068
RIH	+0·125 ± 0·045	−0·138 ± 0·017	+0·016 ± 0·068

It is clear from the above table that only pressure has a real influence on the intensity of cosmic rays, the other factors having a very small and uncertain influence. We have therefore applied only correction for the pressure effect in the present work.

The barometer effect was deduced by arranging the intensities according to different values of pressure, working out their means and then applying the method of regression coefficients. The pressures at the mean times of observation were obtained from the charts of self-recording microbarographs of the Agra and Kodaikanal observatories. During the periods of observation here considered the barometric pressure varied between 28·85″ and 29·09″ at Agra and between 22·69″ and 22·90″ at Kodaikanal. In order to reduce the intensity values for each station to some standard pressure, the following procedure was adopted. All the intensity values were tabulated separately for Agra and Kodaikanal according to different values of pressure at intervals of 0·01″. The mean values of intensity 'I' for different values of pressure P were deduced and the regression coefficients

R between these values were then calculated from the following formula

$$R = \frac{s.\{I(P-p)\}}{s.\{(P-p)^2\}}$$

where p is the mean of all P values.

The regression coefficients derived from Agra and Kodaikanal data are $-0{\cdot}078$ I and $-0{\cdot}040$ I per inch of mercury respectively. With these coefficients the values of I for Agra and Kodaikanal were reduced to the standard pressures of 29·0″ and 22·8″ respectively. We denote these intensity values reduced to standard pressure by I_0.

ABSORPTION COEFFICIENT OF COSMIC RAYS

The mean value of the intensity of cosmic rays at any place depends primarily upon the altitude and the latitude of the station. If for the mean values of I_0 obtained for Agra and Kodaikanal allowance is made for the effect of latitude, then the remaining difference between the intensity values would be mostly due to the effect of altitude and from this the absorption coefficient of cosmic rays can be calculated. The fact that cosmic-ray intensity varies with the geomagnetic latitude* is now well established. The results obtained by Clay, Compton, Hoerlin, Neher and others show that cosmic-ray intensity is nearly constant from about latitude 50° to the pole both in the northern and southern hemispheres, but decreases steadily towards the equator, the decrease amounting to about 14 per cent. at sea level and much higher at higher altitudes. The geographical latitudes of Agra and Kodaikanal are 27° 8′ N and 10° 14′ N and their geomagnetic latitudes are 17° 21′ N and 0° 37′ N respectively. The geomagnetic latitudes were calculated from the formula

$$\sin\lambda = \sin\psi\cos\theta\cos\phi + \cos\psi\sin\theta,$$

where λ is the geomagnetic latitude, ψ the colatitude of the north pole of uniform magnetisation, θ the geographical latitude of the place and $\phi + 69°\,8'$ is the west longitude of the place.

From Compton's [1] intensity geomagnetic latitude curve for sea level (which includes the data of Clay, Millikan and others), the percentage decrease in intensity from latitude 17° to the equator is about 1 and the same from the curve for 2000 metres (about 6600 ft.) altitude is 2·5. The altitude of Agra and Kodaikanal being 554 feet and 7688 feet respectively, the intensity at Kodaikanal has to be increased by 2 per cent. to reduce it to Agra latitude. Then this corrected intensity can be compared with the intensity at Agra and the altitude effect can be deduced.

* By geomagnetic latitude is meant the latitude relative to the pole of uniform magnetisation of the earth which is at 78° 32′ N and 69° 8′ W and is different from the magnetic latitude which is defined by the formula $\tan\mu = \frac{1}{2}\tan\delta$, where μ is the magnetic latitude and δ is the dip of the magnetic needle.

The mean cosmic-ray intensities measured at Agra and at Kodaikanal are $1{\cdot}545 \pm {\cdot}007$ and $2{\cdot}333 \pm {\cdot}010$ ion-pairs cm.$^{-3}$ sec.$^{-1}$ respectively. The intensity at Kodaikanal reduced to Agra latitude would then be $2{\cdot}380$ ion-pairs cm.$^{-3}$ sec.$^{-1}$ We can take it that the intensity of $2{\cdot}380$ ion-pairs cm.$^{-3}$ sec.$^{-1}$ becomes reduced to $1{\cdot}545$ ion-pairs cm.$^{-3}$ sec.$^{-1}$ through absorption by an air column of depth corresponding to $6{\cdot}2''$ of mercury, this being the difference between the mean barometric pressures of Agra and Kodaikanal. Assuming that the cosmic rays are absorbed exponentially, their absorption coefficient can then be calculated by means of the simple formula

$$I_1 = I_2\, e^{-\mu d} \text{ or } \mu = \left(\frac{2{\cdot}3026}{d} \right) (\log I_1 - \log I_2),$$

where μ is the absorption coefficient, I_1 and I_2 are the intensities of rays when they enter and when they leave the absorbing layer respectively, and d is the depth of the layer. Using appropriate values for Agra and Kodaikanal in the above formula we obtain

$$\frac{2{\cdot}306}{6{\cdot}2 \times 13{\cdot}6 \times 2{\cdot}54} \quad (\log 2{\cdot}380 - \log 1{\cdot}545)$$

$$= 0{\cdot}00202 \text{ cm.}^{-2} \text{ gm.}^{-1}$$

$$= 0{\cdot}202 \text{ per metre of water.}$$

This value of absorption coefficient agrees with the values obtained by Millikan and Cameron [5] in their experiments in the high altitude lakes of America.

ABSOLUTE INTENSITIES OF COSMIC RAYS

The mean cosmic-ray intensity values of $2{\cdot}333$ and $1{\cdot}545$ ion-pairs/cm.^{3}/sec. obtained at Kodaikanal and Agra respectively are those measured inside an iron shield of $5{\cdot}5$ inches thickness. The absolute intensities I_K and I_A (*i.e.*, the intensities without the shield) can be calculated for the two stations from the coefficient of absorption already determined and from the density of iron. We again use the exponential formula $\mu = \frac{2{\cdot}3026}{d}$ $(\log I_1 - \log I_2)$. Substituting the values of μ, d and I_2 for Kodaikanal we have

$$\cdot 00202 = \frac{2{\cdot}3026}{5{\cdot}5 \times 2{\cdot}54 \times 7{\cdot}8} \cdot (\log I_K - \log 2{\cdot}333)$$

or $$I_K = 2{\cdot}907 \text{ ion-pairs cm.}^{-3} \text{ sec.}^{-1}$$

Similarly for Agra we have

$$I_A = 1{\cdot}925 \text{ ion-pairs cm.}^{-3} \text{ sec.}^{-1}$$

The intensities corresponding to the altitudes of Agra and Kodaikanal from Compton's intensity-barometer curve for latitudes $0° - 20°$ are $2{\cdot}8$ and $1{\cdot}7$ respectively. These values lie between those obtained from the present measurements with and without shield. But if we take into account the fact that Compton's values are for a shield of 2·5 cm. of bronze and 5·0 cm. of lead (which roughly corresponds to about half the thickness of the shield used in our experiments), then there is close agreement between these values and those arrived at in the present paper.

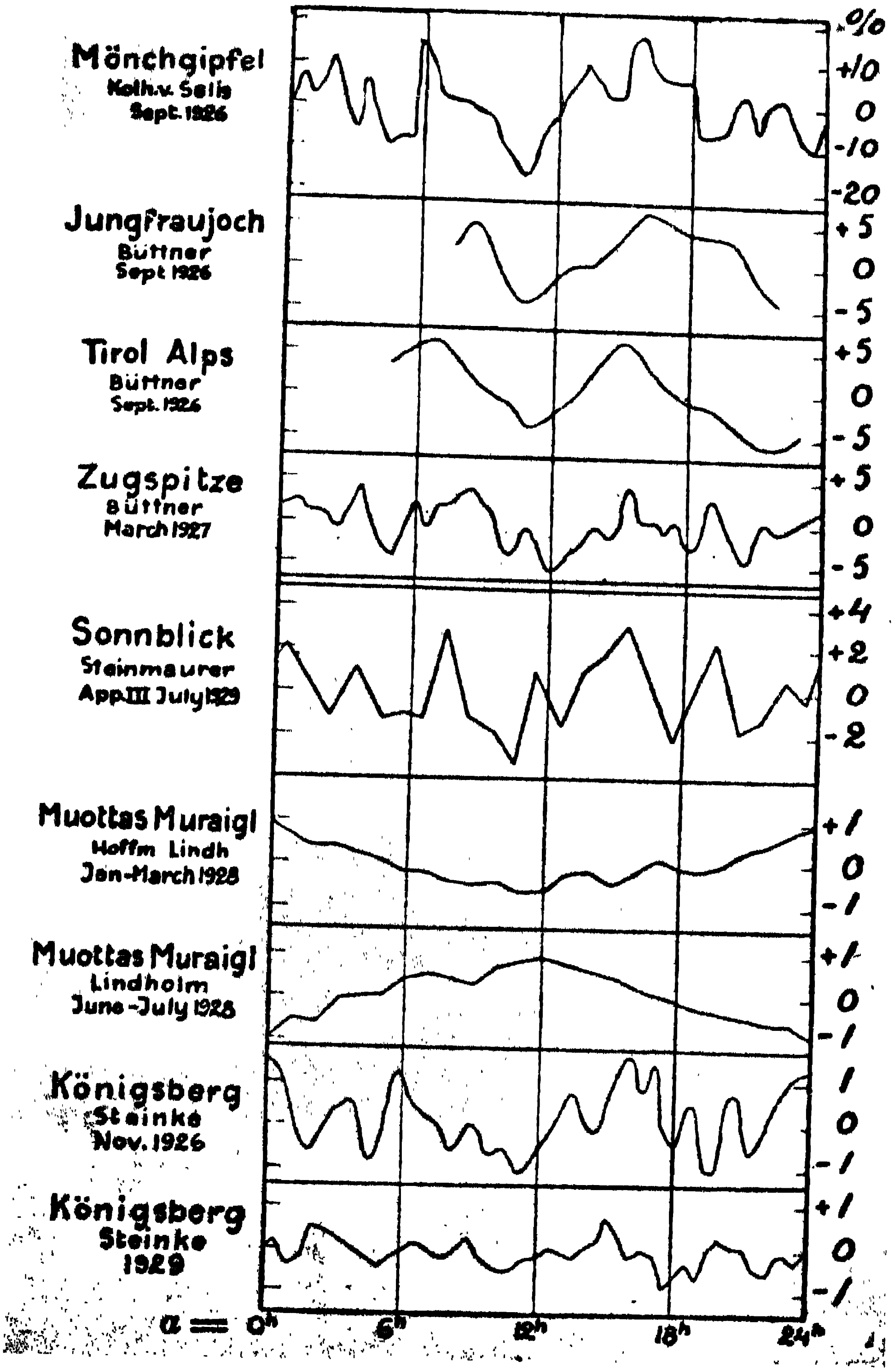
DIURNAL VARIATION OF COSMIC-RAY INTENSITIES WITH SIDEREAL AND MEAN TIMES

During 1926-29 a number of investigators were engaged in finding out whether the intensity of cosmic rays varied with sidereal time. In 1926 W. Kolhörster and G. v. Salis from their observations in Mönchgipfel in Switzerland found variations up to 15 per cent. following a daily period according to sidereal time with maximum at 6^h and 16^h and minimum at about 10^h. Later Büttner, Steinmaurer and Steinke from their observations at different places confirmed the results of Kolhörster and v. Salis. The results obtained by different investigators were plotted by A. Corlin [6] and are reproduced here in Figure 1. As will be seen, all these curves agree with one another excepting those of Lindholm at Muottas Muraigl. Corlin [7] also got the same results as Kolhörster and others by analysing his data at Abisko.

But later observations by a number of other investigators did not confirm these results. Among the later observations may be mentioned those of R. Steinmaurer at Sonnblick (1929-30), of Lindholm at Stockholm (1930-31) and of Compton and others at Mt. Evans (1931). Though these investigators did not find any unquestionable variations in intensity according to sidereal time, yet when their data were analysed and plotted against mean solar time, they found very good agreement in all the curves with maximum at noon or in the afternoon. These curves are also reproduced here in Figure 2 from Corlin. [8]

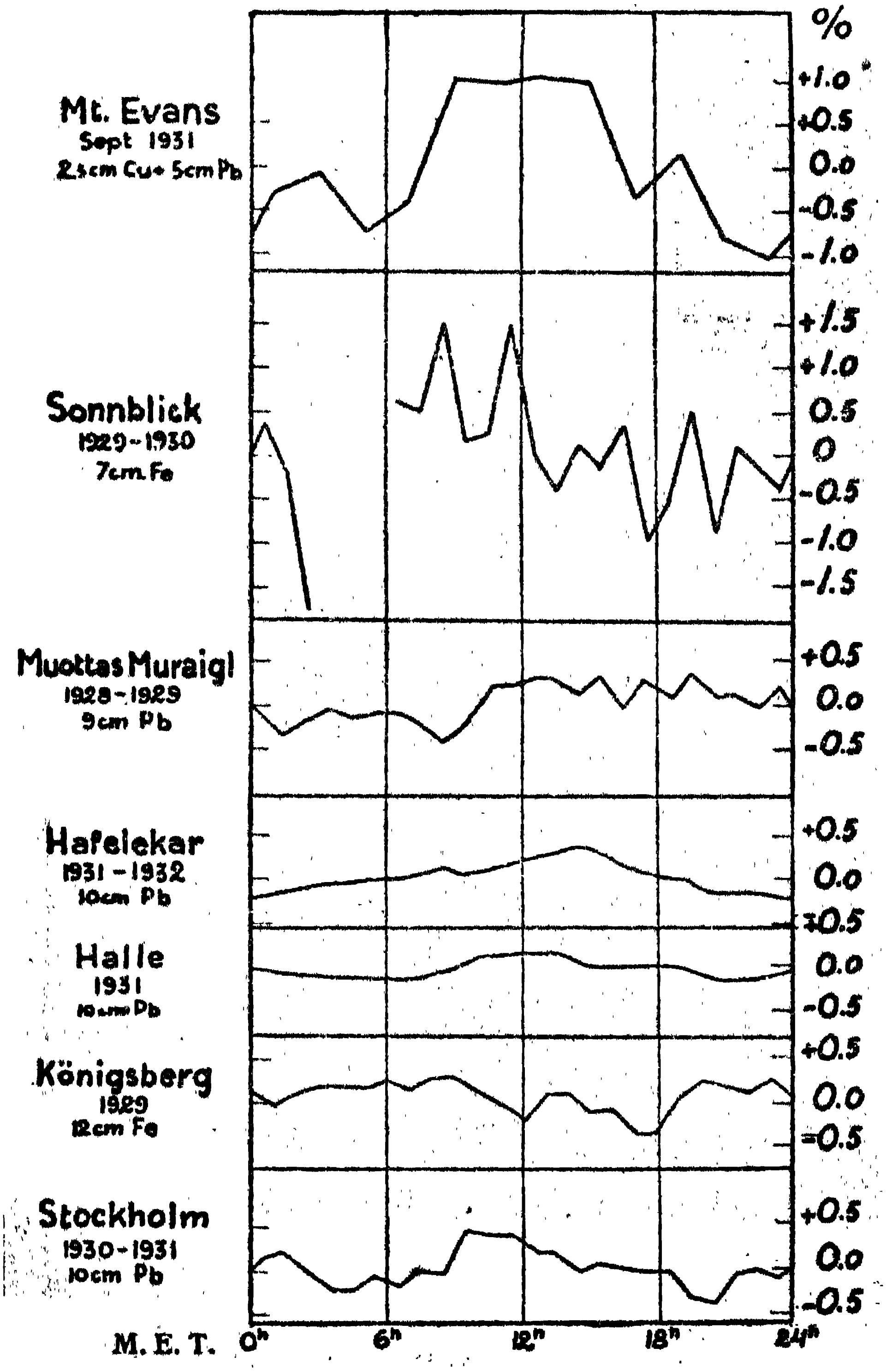
The intensity data for Agra and Kodaikanal were analysed according to sidereal and mean solar times to see how far they agreed with the results of other investigators. To get the mean hourly intensity values according to sidereal time, all the mean times of observation were converted to sidereal times. Intensity-sidereal time curves were then drawn for every day From these curves the intensity values at every sidereal hour were read off and their means for each hour were calculated for Agra and Kodaikanal separately. Similarly mean hourly intensity values were calculated according to mean solar time (in this case Indian Standard Time). These values were plotted separately for Agra and Kodaikanal and are shown here in Figure 3.

It will be seen from Figure 3 that the mean time curves for Agra and Kodaikanal agree with each other and also with those of other investigators shown in Figure 2. Both these curves show a maximum intensity in the afternoon (Agra



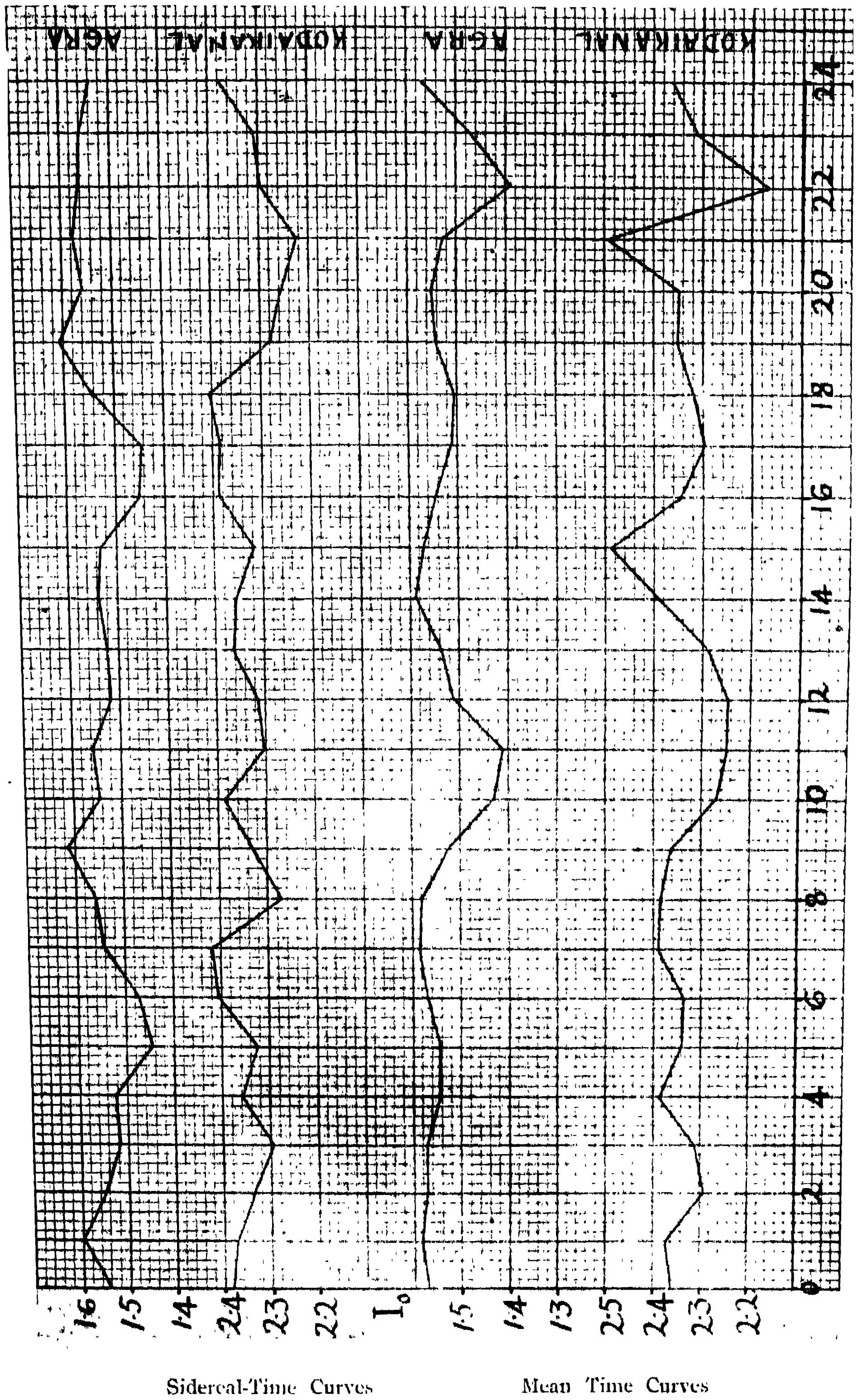
The sidereal time period as observed in 1926-29

FIGURE 1



The mean time period as observed with closed shield in 1929-32.

FIGURE 2



Hours

FIGURE 5

at 14^h and Kodaikanal at 15^h) and minimum intensities at 11^h and 22^h. But the sidereal-time curves for these two stations do not show any conformity either with each other or with corresponding curves of other investigators shown in Figure 1. On the other hand, a close examination of these two curves shows that they are more or less opposite in phase, *i.e.*, the minimum in the curve of one station corresponding to the maximum of the other. This can be explained by the fact that the Kodaikanal data refer to the month of February and that of Agra to the months of June-July. Between the corresponding sidereal times of February and July there is a difference of about 12 hours according to mean time, and as these curves agree according to mean time, they are opposite in phase according to sidereal time. Therefore, it can be said that the Agra and Kodaikanal data do not confirm the results of Kolhörster and others but confirm those of later investigators who find variations according to mean solar time.

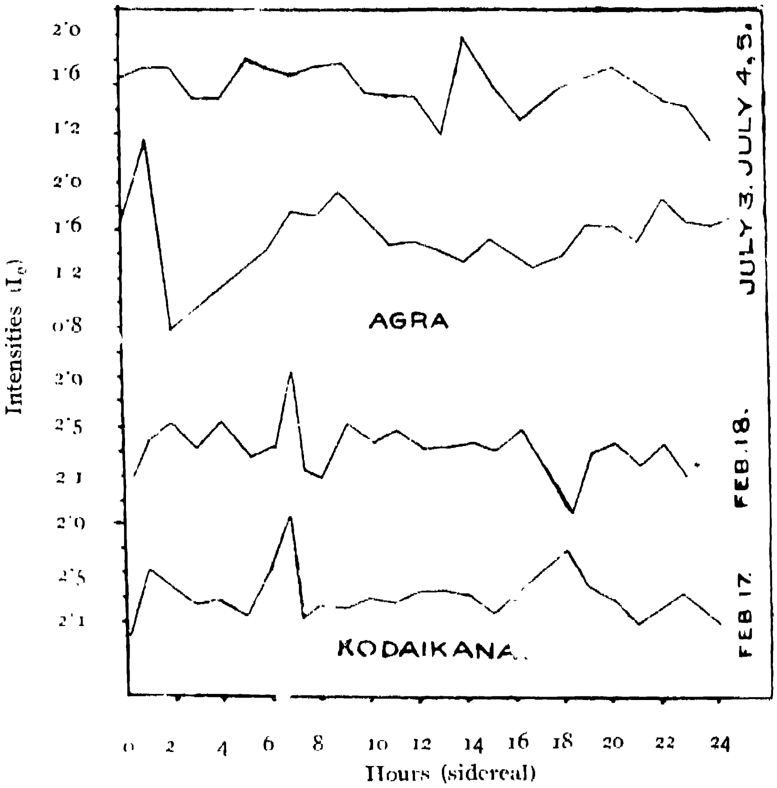


FIGURE 4

But it should be noted that the data of Agra and Kodaikanal are very meagre to draw any definite conclusions. For such kind of work, data ranging over very long periods are required so as to minimise the effect of abnormal changes (the so-called "variations of the second kind") often shown by cosmic-ray intensity from hour to hour. These variations of the second kind can be seen from the curves given in Figure 4 where the intensities for two days each for Agra and Kodaikanal are plotted against sidereal time. But in the mean curves shown

TABLE 1

Solar activity and cosmic-ray intensity (Agra)

Date	Daily mean sunspot numbers	K Flocculi figure	H, Bright Flocculi figure	H, Dark Flocculi figure	Sum of the 3 Flocculi figures	Mean daily cosmic-ray intensity
18-6-36	60	2.8	2.8	2.3	7.9	1.344
19-6-36	101	3.0	2.9	2.5	8.4	1.326
20-6-36	88	3.0	3.0	2.2	8.2	1.214
21-6-36	119	3.1	2.8	1.8	7.7	1.566
22-6-86	100	2.9	3.0	[illegible]	8.1	1.475
23-6-36	76	3.0	2.7	2.0	7.7	1.544
24-6-36	71	3.1	2.8	2.4	8.3	1.585
25-6-36	89	3.2	3.0	2.5	8.7	1.622
26-6-36	112	3.1	3.5	2.2	8.8	1.512
27-6-36	103	3.2	3.5	2.8	9.5	1.621
29-6-36	68	2.8	2.7	2.8	8.3	1.383
30-6-36	79	2.8	2.8	3.2	8.8	1.590
1-7-36	79	2.9	3.0	3.0	8.9	1.550
2-7-36	74	3.0	3.0	3.0	9.0	1.585
3-7-36	44	2.9	2.0	2.8	7.7	1.596
4-7-36	50	2.9	2.7	3.0	8.6	1.616
5-7-36	52	2.8	2.8	2.2	7.8	1.670
7-7-30	30	2.5	2.0	2.1	6.6	1.537
8-7-36	47	2.4	2.0	2.0	6.4	1.561
9-7-36	43	2.6	2.1	1.8	6.5	1.571
10-7-36	47	2.8	1.5	1.5	5.8	1.572
11-7-36	49	2.1	2.0	2.0	6.1	1.574
13-7-36	67	2.9	2.2	1.0	6.1	1.502
14-7-36	76	2.9	2.5	1.0	6.4	1.607
15-7-36	67	3.1	2.7	1.0	6.8	1.[illegible]58
16-7-36	69	3.1	2.8	1.0	6.9	1.370
17-7-36	57	2.9	2.8	1.0	6.7	1.576
18-7-36	53	3.1	3.0	1.0	7.1	1.566

TABLE 2

Solar activity and cosmic-ray intensity (Kodaikanal)

Date	Daily mean sunspot figure	K Flocculi figure	H_α Bright Flocculi figure	H_α Dark Flocculi figure	Sum of the 3 Flocculi figure	Mean daily cosmic-ray intensity
9-2-38	101	3.1	2.8	2.8	8.7	2.211
10-2-38	133	3.4	4.0	3.5	10.9	2.303
11-2-38	137	3.8	3.3	3.6	10.0	2.376
12-2-38	101	3.8	4.2	4.5	12.5	2.230
13-2-38	100	3.8	4.3	3.7	11.8	2.352
14-2-38		4.2	5.0	5.0	14.2	2.393
15-2-38		4.1	5.0	3.0	12.1	2.346
16-2-38		4.4	5.0	[illegible]	11.4	2.331
17-2-38	171	4.1	1.8	[illegible]	11.4	2.353
18-2-38	171	4.1	5.0	2.0	11.4	2.355
19-2-38	145	3.9	1.1	2.6	10.6	2.342
20-2-38	98	3.8	4.0	2.2	10.0	2.286
21-2-38	100	3.2	3.5	2.0	9.6	2.379

in Figure 3 these variations are much less pronounced and if longer periods are taken the curves may be expected to become very much smoother.

COSMIC RAYS AND SOLAR ACTIVITY

Whether the sun at all contributes to the intensity of cosmic rays does not seem to have been conclusively established. Some observers have, however, claimed to have detected a small solar contribution as the result of their analysis of a long series of measurements. Another way of detecting solar influence on cosmic-ray intensity is to correlate the mean daily intensity with solar activity. Accordingly the mean daily cosmic-ray intensities for Agra and Kodaikanal were calculated from the values of I_0 and the sunspot numbers and flocculi figures were taken from the quarterly bulletins for character figures of solar phenomena published under the auspices of the International Astronomical Union. In the bulletins the flocculi figures are given separately for calcium flocculi, H_α bright markings and H_α dark markings, each for the whole disc and for the inner circle (half the radius of disc) of the sun. The sum of the three 'whole disc' figures was taken for the purpose of correlation. All these results are collected in Tables 1 and 2 for Agra and Kodaikanal respectively. These figures were plotted as dot diagrams in order to see whether any relationship exists either between the intensity and flocculi figures but no relationship of any kind was detected. The data considered are, however, very meagre for drawing any definite conclusions.

The senior author takes this opportunity of thanking Dr. C. W. B. Normand, C.I.E., Director-General of Observatories, for purchasing the Kolhörster apparatus at his request. He is indebted also to Rai Bahadur G. Chatterjee, Superintending Meteorologist, Agra, who had the iron shield constructed at the Agra Observatory besides providing him with all facilities for the part of the work done at Agra and Dr. N. K. Sur, Meteorologist, for the valuable assistance he gave him in the reduction of the cosmic-ray records at Agra. Our thanks are also due to Dr. A. L. Narayan, Director of the Kodaikanal Observatory, for his interest in the part of the work done at Kodaikanal.

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